Office of Field Support:BLee:3-4884

RISK REDUCTION OF DEPARTMENT OF ENERGY (DOE) WATER TREATMENT OPERATIONS

Distribution

In line with the Secretary's directive to identify chemical safety vulnerabilities at DOE facilities and to reduce exposure of workers and the public to hazardous chemicals, an analyses of DOE water treatment operations was performed. Chlorine gas is the most commonly used chemical for water treatment at DOE facilities. However, large chemical companies, commercial nuclear plants, and numerous municipalities have switched to safer chlorine gas alternatives for their water treatment. Within the DOE complex, the Savannah River Site has, over a five year period, successfully replaced chlorine gas with hypochlorite and other substitutes for all its water treatment needs. DOE statistics indicate that chlorine gas incidents occur, on the average, about every six months and that almost 30 percent of these involve personnel exposure to chlorine requiring medical attention.

Following a chlorine release incident at Argonne-West in April 1994 that involved site evacuation of 900 employees with 20 employees receiving medical attention and one employee hospitalized, a Type A Accident Investigation was performed. Lessons learned from the accident were discussed at a complex-wide workshop in August 1994 and resulted in safe practice recommendations for improving DOE chlorine operations. In September and October, 1994, seven facilities representative of chlorine operations across the department were reviewed for program deficiencies. The review findings reinforced the need for guidance in assuring safe chlorine operations.

The attached analysis report summarizes the problems associated with gaseous chlorine use and recommends the use of chlorine gas alternatives whenever possible. For those situations where alternatives are not feasible, the report offers guidance for upgrading chlorine operations.

We would like to know what your plans are for handling chlorine-related concerns at your site and offer you assistance in solving these problems. Should you have any question, I would be happy to discuss this with you. My staff contact for this subject is Billy Lee who may be reached on (301) 903-4884 in Germantown.

Robert W. Barber
Director
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Attachment 1

ANALYSIS OF DEPARTMENT OF ENERGY (DOE) CHLORINATION OPERATIONS

Background

Gaseous chlorine is the most commonly used chemical for water treatment at DOE facilities. Chlorine gas is highly corrosive in the presence of moisture and, when inhaled, could result in irreparable damage to the respiratory system with lethal consequences. Even brief exposure to the toxic gas causes tearing, choking, and an inability to breath or to scream. The hazards of chlorine use have led large chemical companies, such as Rohm and Haas, DuPont, and Monsanto to abandon chlorine for less hazardous methods of disinfecting water at their sites. Most commercial nuclear plants have switched to gaseous chlorine alternatives for biofouling treatment of cooling water. New Jersey's Toxic Catastrophe Prevention Act has led to major statewide reductions in hazardous substances including the use and inventories of gaseous chlorine. In 1989, a chlorine gas explosion at the water treatment plant in Alexandria, Virginia, closed part of the Capital Beltway and forced officials to evacuate 80 people who lived near the plant. In August 1994, two fishermen on the Potomac River were nearly overcome by a cloud of chlorine gas leaking from the District of Columbia's Blue Plains Sewage Plant and had to spend the night in the intensive care unit of a nearby hospital. Alexandria, Blue Plains, and numerous facilities in New Jersey are part of a growing number of municipalities nationwide that have switched to sodium hypochlorite or are considering the use of the chemical for treatment of wastewater and drinking water. Within the DOE complex, storage and use of chlorine cylinders above 100 pounds are found in 56 known locations. Statistics on DOE accidents and incidents (Appendix A) indicate that a chlorine gas leak or incident occurs, on the average, about every six months and that almost 30 percent of these involve personnel exposure to chlorine requiring medical attention.

In April 1994, about 20 pounds of chlorine gas was released from a supposedly "empty" cylinder at the Argonne National Laboratory - West (ANL-W). Forty employees were exposed to the gas with 20 of them receiving medical care and one employee hospitalized overnight. The Office of Environment, Safety and Health established a Type A Accident Investigation Board to investigate the chlorine release. Although no serious injuries resulted from the accident, a high potential for serious injury existed. A brief account of the ANL-W incident is given in Appendix B. Lessons learned from the accident were discussed at an August 1994 complex-wide workshop held in Idaho Falls with the objective of developing guidance for the risk reduction of DOE chlorine operations. In September and October 1994, the chlorine operations at seven facilities, representative of chlorine operations across the Department, were reviewed for program deficiencies by the IT Corporation for DOE. A copy of the IT report is attached.

Lessons Learned

The lessons learned from the ANL-W accident and guidance from the workshop for handling and storing chlorine gas cylinders are summarized as follows:

- Access to chlorine gas systems should be restricted to personnel who are specifically qualified to work on or near these systems.
    - Limit accessibility to cylinders by securing them in locked areas.
    - Provide operations training to ensure that personnel have an appropriate level of knowledge and skill for changing out gas cylinders safely.
- A formal work control system should be required for chlorine gas cylinder changeouts.
- General procedures for gas cylinder changeout should address the hazards associated with cylinder changeouts for specific gases.
- Personnel should wear appropriate protective equipment, including full-face respirators, long-sleeved

shirts, leather gloves, and hard hats.

- Safe practices should be identified and proper procedures should be implemented to reduce the risk of leaks during chlorine cylinder changeouts.

  - Always use the buddy system during changeouts.

  - Never use lubricants on gas cylinder parts.

  - Follow basic good practices given in the Occupational Safety and Health Observer poster (Appendix C).

- A general inspection of the chlorine gas system station should be accomplished during each cylinder changeout for potential operational or maintenance deficiencies.

- Rescue capabilities, including appropriate medical resources, must be preplanned and exercised.

  - Provide the emergency response team with information about the time and location of planned changeouts for chlorine gas cylinders.

- Pertinent lessons learned incidents should be communicated to all employees that could be affected.

DOE Facility Reviews

The need for guidance for risk reduction of the DOE chlorine operations is apparent from the IT review of existing DOE facilities. The review indicated that one or more of the facilities inspected had operational deficiencies in the following areas:

- Formal work request and job safety analysis for chlorine container changeover.

- Training for container changeover, hazard communication, and emergency response.

- General and routine inspections.

- Use of tags (Full, In Service, Empty).

- Respiratory protection.

- Posting of evacuation routes.

- Keeping emergency response plans current.

- Use of lessons learned incidents.

All of these deficient areas have been covered by and reinforces the importance of the ANL-W lessons learned and the workshop recommendations. The IT review further indicated that safe practices for chlorine operations must include equipment review. One facility did not have chlorine sensors in place and two facilities did not have vacuum regulators on their cylinders. Vacuum regulators are the most important devices to prevent system leaks (not including cylinder leaks). The chlorine sensors and vacuum regulators have been installed since the review.

Summary

Risk reduction of the DOE chlorine operations could be accomplished by using chlorine gas alternatives and by upgrading programs, procedures, and practices associated with the use of chlorine. Proposed new water treatment facilities, aging facilities, and facilities that pose potential hazards to collocated workers and the public should consider switching to sodium hypochlorite or other gaseous chlorine alternatives. A cost comparison for hypochlorite and gaseous chlorine systems, given in Appendix D, indicates that hypochlorite systems have significantly lower installation costs, especially when large water treatment facilities are involved. The DOE site at Savannah River (SR) has been successful with their sodium hypochlorite treatment of drinking water and wastewater over the past five years. For wastewater treatment, SR has recently changed to an ultraviolet system to avoid the expense for dechlorination and to reduce maintenance costs. This information is provided in Appendix E. For facilities using chlorine gas for research and development, and those operating treatment facilities that have valid reasons for not changing to a chlorine gas alternative, the lessons learned from the ANL-W incident, guidance developed from the complex-wide workshop, and the review findings on the seven DOE facilities should be helpful for improving their chlorine operations.

The Department of Energy (DOE) Chlorine Gas Accidents and Incidents

The two primary sources of chlorine gas accident and incident data at DOE facilities are the Safety Performance Measurement System (SPMS) and the Occurrence Reporting and Processing System (ORPS). The SPMS contains records of injuries, illnesses, and property losses for DOE and contractor organizations from 1981 to 1991. The ORPS contains information on emergencies and unusual or off-normal occurrences at DOE facilities in accordance with DOE 5000.3A. ORPS contains occurrence data from January 1990 to the present. The data on chlorine gas accidents and incidents at DOE indicate that a chlorine gas leak or incident occurs, on the average, about every six months and that almost 30 percent of these involve personnel exposure to chlorine requiring medical attention. The data analysis does not include incidents with dry and liquid chlorinated chemicals or accidents where gaseous chlorine is generated as a consequence of chemical reactions.

Chlorine Incident at Argonne West

On April 15, 1994, at Argonne National Laboratory-West (ANL-W), a plant service employee (alternate tool crib operator) attempted to remove the yoke and regulator from what he believed to be an empty chlorine cylinder. About 20 pounds of chlorine gas was released. Because of the location of the release, 900 employees were evacuated from the facility in approximately 9 minutes; 40 employees were exposed to the chlorine gas; 20 employees were transported to the regional medical center; and one employee (the alternate tool crib operator) was hospitalized overnight. No permanent injuries were reported.

The Accident Investigation Board found that the operator was not authorized to conduct chlorine cylinder-related operations and that he had received no training in this area. In addition, there was no written, approved procedure for this activity, nor was there a system safety analysis or a specific job safety analysis performed.

Several findings were noted, most of them related to DOE 5480.19, "Conduct of Operations:"

- Procedures that might have prevented this event did not exist.

- Personnel training and understanding of job-specific functions performed by the tool crib alternate were insufficient.

- The use of lessons learned from similar nonnuclear incidents within the Department was inadequate.

- Oversight of the nonnuclear operations performed by ANL-W and the DOE areas office was deficient.

Cost Comparison For Hypochlorite and Gaseous-Chlorine Systems

Sodium hypochlorite has been successfully used as a disinfecting agent for drinking water and wastewater at the Savannah River Site (SRS) for many years. At our request, Savannah River has provided approximate cost comparisons for comparable hypochlorite and gaseous chlorine treatments for drinking water and also estimates for making the changeover from existing gaseous chlorine systems to hypochlorite. This information is given in Table 1.

Table 1. Comparison of 1995 capital costs for hypochlorite and gaseous chlorine treatment of drinking water*

System Size (MGD)	**Gaseous Chlorination** ($ in thousand)	**Hypochlorite** ($ in thousand)	**Changeover from Gaseous Chlorine to Hypochlorite** ($ in thousand)
0.01	25-30	< 7.5	< 7.5
2.0	250-300**	200-250	30-40

* Based on discussions with Robert Turner at Westinghouse Savannah River (Telephone: 803-725-3627)

** Does not include cost of scrubber system

For a small 0.01 million gallon per day (MGD) hypochlorite system, the setup could be simple and inexpensive. A well house system, for example, requires basically a 15 gallon jug of hypochlorite, a 10 gallon mixing container, and a portable feed pump. A comparable treatment system with gaseous chlorine costs much more due to more elaborate equipment, a containment room for the chlorine gas, a room for feeding chlorine, and a place for housing respirators nearby. For larger treatment systems, the hypochlorite process is still significantly less expensive. The data in Table 1 also indicates that the cost for a changeover from gaseous chlorine to hypochlorite is a fraction of the cost for a new system.

The operating, maintenance, and chemical costs for hypochlorite and gaseous chlorine systems, each having a capacity of 0.01 MGD, are given in Table 2. These costs are derived from the data sheets in the EPA/625/4-89/023 document dated March 1990. Data in the EPA document goes back to as early as 1980, and a five percent annual adjustment for inflation was assumed to give the 1995 estimates.

Table 2. Annual operating, maintenance, and chemical costs (1995 estimates) for two 0.01 MGD systems

System	**Capital Expense** ($ in thousands)	**Operating and Maintenance** ($ in thousands)	**Chemicals** ($)
Gaseous Chlorination	20-30	4.5	160.
Hypochlorite	7.5-22	7.4	190.

The higher annual costs of operation and maintenance for the hypochlorite system is mainly attributed by EPA to approximately one hour of labor required each day to mix the sodium hypochlorite solution.

For DOE facilities, these higher costs for operations, maintenance, and chemicals for hypochlorite systems are offset by lower costs in other operational areas required by facility safety and health programs. The costs associated with the intensive personnel training required for gaseous chlorine operations and storage, inspection, and maintenance of respirators at the treatment areas do not apply for hypochlorite systems.

The capital costs for the 0.01 MGD system with hypochlorite in Table 2 are higher than those in Table 1 because the basic EPA system costing $7,500 includes two metering pumps (one serving as a standby) and a more substantial solution tank and diffuser. The most expensive ($22,000) system from the EPA document results mainly from the addition of a $14,000 safety housing enclosure.

Environmental regulations require that chlorinated wastewater be dechlorinated prior to its discharge to receiving streams. Table 3 gives 1995 cost estimates on chlorination and dechlorination based on fact sheets provided by Metcalf and Eddy. A five percent annual adjustment for inflation was assumed in arriving at the 1995 estimates.

Table 3. Gas chlorination and dechlorination (sulfur dioxide) construction costs in 1995*

System Size (MGD)	**Chlorination** ($ thousand)	**Dechlorination** ($ thousand)
0.1	55	20
1.0	125	40
2.0	175	55
10.0	450	110

* Based on Metcalf and Eddy Fact Sheets provided by Nancy Gonce (Telephone: 404-881-8010) assuming five percent annual adjustment for inflation.

All cost estimates given in the Tables are "ball-park" figures and depend on many variables such as the complexity of a system, type of safety enclosure used, and area-based siting and construction costs. An estimated cost of $175,000 for a 2 MGD chlorination system in Table 3 is consistent with the $250,000 estimate for the same size system in Table 1.

Gas chlorination often requires the use of a chlorine gas scrubber to prevent significant leaks to the environment. Scrubber equipment, however, adds significantly to the overall costs for the system. The cost estimate given in Table 4 for the proposed Parkway Wastewater Treatment Facility at Laurel, Maryland indicates that the chlorination-dechlorination system with a gas scrubber costs more than three times the cost for an equivalent hypochlorite system.

Table 4. Proposed chlorination/dechlorination alternatives for a 7.5 MGD wastewater treatment system at the Parkway, Laurel Facility*

Alternative	**Capital Costs** ($ thousand)	**Annual Chemical Costs** ($ thousand)
Gas Chlorine/Sulfur Dioxide (with gas scrubber)	2200.	73.
Sodium Hypochlorite/ Sodium Bisulfite	605.	147.

* References: Messrs: Charles Sheetz and Kenneth Graham, Washington Suburban Sanitary Commission (Telephone: 301-206-7423)

The primary reason for using chlorine gas alternatives should be for worker and public safety. However, the analysis also gives an economic incentive for not using chlorine gas systems. The data indicates that hypochlorite systems, in general, have lower installation costs with a substantial economic advantage over those gaseous chlorine systems that are sufficiently large to require scrubbers. Hypochlorite systems have higher maintenance and chemical costs, but these costs are offset by lower costs in other operational areas required by facility safety and health programs. Use of hypochlorite should be considered even when existing or new gaseous chlorine systems are in place. Costs for change over from an existing gaseous chlorine operation to hypochlorite are only about 10-15 percent of the expense for new chlorination systems.

Utilization of Ultraviolet Light for Wastewater Disinfection at Savannah River Site (SRS)

Introduction

SRS operates 20 small package wastewater plants to handle sanitary wastewater from the employee population. Sodium hypochlorite has been used as a disinfecting agent at these plants for over five years. Although sodium hypochlorite is a highly effective disinfectant, new environmental regulations require a modification to these systems in order to prevent discharges of chlorine into receiving streams. The current disinfection systems would either have to be retrofitted to include dechlorination systems or replaced with a system that did not use chlorine products. A retrofit would cost more than the inclusion of a dechlorination system. The existing chlorination process would have to be modified at almost the cost of new construction because additional pumps and equipment would be required. After careful study of all of the available options, SRS personnel chose to replace hypochlorite with ultraviolet (UV) light disinfection systems.

Alternatives Studied

The following alternatives were studied:

Chlorination	Dechlorination	Other
gas chlorine sodium hypochlorite calcium hypochlorite	sodium metabisulfite sodium sulfite sodium bisulfite sulfur dioxide aeration activated charcoal	hydrogen peroxide ozone bromine uv light

Factors considered for each alternative included:

- life cycle cost
- availability
- hazardous properties (safe handling & storage)
- impact on receiving stream
- disinfection effectiveness
- reliability

Many of these alternatives were eliminated early on as being unacceptable. For example, gaseous chlorine was eliminated from consideration because of the dangers of a gas leak to workers and the public, while bromine was eliminated due to its effect on the receiving stream.

UV light and sodium hypochlorite with sodium sulfite addition were chosen as the two most effective alternatives. A pilot plant study of UV light was performed on site to confirm its effectiveness on SRS wastewater, and detailed cost estimates were prepared for both alternatives. UV light was the preferred alternative due to the following:

- low capital cost
- low operating & maintenance costs
- elimination of hazardous chemical handling & storage
- elimination of aquatic toxicity in receiving streams from chemical addition
- proven effective as a disinfectant on SRS waste streams
- high level of system reliability when compared with flow paced chemical addition

Cost Comparison

The following cost comparison was made based on converting six of the package plants to UV light. These plants vary in size from 10,000 to 35,000 gallon per day (GPD).

	Construction	Operation ($/yr)
Chlorination/Dechlor	$1,140,000	$4,485
UV Light	$ 580,000	$1,950
Cost Savings	$ 560,000	$2,535

Construction cost savings (50%) were significant even when considering only six small plants. Most of the capital savings came from the elimination of chemical mixing facilities, storage tanks, and the required complex controls needed to operate a flow paced chlorination/dechlorination process. Operating costs, mainly chemical costs, are also cut in half; however, operating costs are fairly insignificant in comparison to capital costs.

Project Status

SRS initiated a project to replace 14 of its 20 sanitary plants with a centralized sanitary wastewater treatment facility (CSWTF). This project included the use of UV light as the disinfection technology for the new 1.05 million gallon per day CSWTF as well as using UV light to replace the present chlorination systems at the remaining six package wastewater treatment plants. To date, approximately $1 million in capital cost savings have been returned to the Department of Energy by the project because of the use of UV light as the chosen disinfection technology. The first of the small UV systems has been successfully placed in service. Fecal coliform testing has not been able to detect any bacterial colonies in the UV effluent. All of the UV systems will be placed in service in 1995.

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